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Size-dependent resistance of protected areas to land-use change

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One of the major threats facing protected areas (PAs) is land-use change and habitat loss. We assessed the impact of land-use change on PAs. The majority of parks have been effective at protecting the ecosystems within their borders, even in areas with significant land-use pressures. More in particular, the capacity of PAs to slow down habitat degradation and to favour habitat restoration is clearly related to their size, with smaller areas that on average follow the dominant land-use change pattern into which they are embedded. Our results suggest that small parks are not going to be viable in the long term if they are considered as islands surrounded by a 'human-dominated ocean'. However, small PAs are, in many cases, the only option available, implying that we need to devote much more attention to the non-protected matrix in which PAs must survive.

Keywords: Italy; protected areas; land-use change; single large or several small; false discovery rate; *q*-value

1. INTRODUCTION

Protected areas (PAs) are widely recognized as the most important tool available for 'in situ' conservation (Bruner *et al.* 2001; Sinclair *et al.* 2002; Sànches-Azofeifa *et al.* 2003; Chape *et al.* 2005; Lovejoy 2006). However, in many cases it has been demonstrated that PAs do not adequately represent the biodiversity of a region (Pressey *et al.* 1993; Scott *et al.* 1993; Rodrigues *et al.* 1999; Maiorano *et al.* 2006). The recent world GAP analysis showed that at least 12% of all terrestrial vertebrates are not covered by any existing PA and that more than 75% of them do not achieve their representation target (Rodrigues *et al.* 2004). Moreover, different studies have demonstrated that existing PA networks are too small to represent a viable solution for the conservation of biodiversity, especially in human-dominated landscapes (Tilman *et al.* 2002; Carroll *et al.* 2004; Maiorano *et al.* 2007).

One of the most important threats facing PAs is land-use change and the related habitat loss (Sala *et al.* 2000; Brooks *et al.* 2002). In particular, Hoekstra *et al.* (2005) have demonstrated that habitat conversion exceeds habitat protection by a ratio of 8 : 1 in temperate grasslands and Mediterranean forests and 10 : 1 in more than 140 ecoregions.

Different studies have analysed the effectiveness of PAs in protecting biodiversity and the results are not univocal, probably because many context-dependent factors may affect the relationship of a PA and its surrounding area. Bruner *et al.* (2001) examined the effectiveness of PAs in the tropics, drawing on survey data to support the conclusion that parks have been effective at preventing land clearing within their boundaries. However, Vanclay (2001) re-examined the same dataset and obtained different results, concluding that the results obtained by Bruner *et al.* (2001) remain equivocal. Other studies have demonstrated that PAs have been effective in preventing deforestation and habitat loss (Nagendra *et al.* 2004; Nepstad *et al.* 2006), but there are many cases where existing PAs have not been able to stop habitat degradation (Schwartzman *et al.* 2000; Curran *et al.* 2004; Fuller *et al.* 2004; Sigel *et al.* 2006; Verburg *et al.* 2006; Gaveau *et al.* 2007), possibly owing to ineffective management strategies (Ervin 2003).

Most of the studies have dealt with tropical PAs located in areas where high human population growth rates, land-use intensification and loss of natural habitat are common features (Houghton 1994; Dobson *et al.* 1997; Matson *et al.* 1997; Lambin *et al.* 2003; Sodhi *et al.* 2004; Brown *et al.* 2005; Lepers *et al.* 2005). It is not clear whether the results of these studies can be applied to the completely different context of the Mediterranean basin (Falcucci *et al.* 2007).

Moreover, nobody has explicitly considered PA size in relation to their capacity to slow down land-use change, even though a great deal of work was focused on the size of PAs in relation to their efficiency in preserving biodiversity during the single large or several small (SLOSS) debate (Margules *et al.* 1982; Soulé & Simberloff 1986; Ovaskainen 2002). A number of papers (reviewed in Ovaskainen 2002) supported that several small PAs are better if the objective is that of maximizing the number of species occurring in a system of conservation areas. If the objective is that of maximizing the time to extinction for each species, large PAs should be the preferred solution (Burkey 1989, 1995, 1997; Ovaskainen 2002), but if the objective is that of maximizing the number of species that will eventually survive, the advantages of large PAs over small PAs are not always clear (Simberloff & Abele 1976),

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and if the object is that of maximizing the metapopulation capacity of a PA system (Hanski & Ovaskainen 2000), an intermediate solution is the best option. Clearly, no single solution is optimal in all cases because there is no possibility of generalizing the number, size and location of habitat patches needed to preserve biodiversity (Soulé & Simberloff 1986).

These suggestions cannot be generalized to include the effect of PAs over land-use change. Here, we provide such generalization, reporting the first analysis of the efficacy of PAs at halting (or at least reducing) habitat degradation in a human-dominated landscape. Our study area is Italy and our hypothesis is that there is a relationship between the size of PAs and their resistance to land-use change, with smaller areas being influenced by the surrounding environment more extensively than larger areas.

2. MATERIAL AND METHODS

We measured land-cover/land-use change from 1990 to 2000 using two CORINE land cover maps, one for 1990 (CLC1990) and the other for 2000 (CLC2000). The two maps are part of the programme started in 1985 by the European Community to generate digital land-use/land-cover maps covering the European continent (EC 1993) and were produced using satellite images (Landsat 5 TM for CLC1990 and Landsat 7 ETM+for CLC2000) and other ancillary data (Digital Elevation Model, hydrology and aerial photos). The maps have spatial detail comparable to that of a paper map on a scale of 1 : 100 000 and a hierarchical legend with five classes at the first level. For the purposes of the analyses, we distinguished the five classes into two main categories: artificial land-use/land-cover classes (class 1, artificial surfaces and class 2, agricultural areas) and natural land-use/land-cover classes (class 3, forests and seminatural areas; class 4, wetlands; and class 5, water bodies).

We obtained a detailed dataset on PAs from Maiorano *et al.* (2006), comprising 777 PAs covering 96.6% of the total area protected in Italy. The dataset considers the following five different types of areas: national parks, national reserves, regional parks, regional reserves and other PAs. Overall the five types of PA provide the same level of protection, but national parks and national reserves are regulated and managed at the national level, while the other types depend on the local administrative regions. In our analysis, we considered each separated polygon as a single PA and we excluded all the areas for which no change in land-use/land-cover was measured inside the same PA and inside a 2.5 km buffer built around the area. We obtained a final list of 716 areas that have been used in all analyses. All the PAs considered were officially established before 1990 or the same area was subject to some type of conservation before 1990.

For each PA, we calculated the total rate of change in land-use/land-cover (number of cells that changed from artificial to natural and vice versa over the total number of cells), the rate of change towards natural land-use/land-cover (number of cells that changed from artificial to natural over the total number of cells that were classified as artificial in 1990) and the rate of change towards artificial land-use/land-cover (number of cells that changed from natural to artificial over the total number of cells that were classified as natural in 1990).

Since the quantification of reserve performance in slowing or halting land-use/land-cover change is best measured against a baseline that describes the trajectory of the change (Nepstad *et al.* 2006), we considered a 2.5 km buffer around each area and calculated land-use/land-cover change (total change, change towards natural and change towards artificial) inside the buffer. We considered 2.5 km as a reasonable measure to account for the high spatial heterogeneity that characterizes our study area (Falcucci *et al.* 2007); however, we also performed all the analyses for other buffer widths (specifically 1 and 5 km) to verify the sensitivity of our results to this parameter.

Our analyses are sensitive to co-registration errors between the land cover maps of different years and between land cover and park boundaries. We therefore performed all the analyses using three different cell sizes: 100, 200 and 300 m.

Given the highly skewed distribution of the land-use/land-cover change dataset, we used non-parametric statistics to make comparisons among different types of PA and to measure the relationship among PA size and inhibition of land-use/land-cover change. We used Mann–Whitney *U*-test to compare land-use/land-cover changes (total change, change towards natural and change towards artificial) inside PAs and inside the buffer. We used Kruskal–Wallis one-way analysis of variance for independent samples to compare the inhibition of total land-use/land-cover change across the five reserve types followed by Fisher's protected least significant difference to perform comparisons among reserve types.

To explore the relationship existing between PA size and their efficacy in slowing down or stopping land-use/land-cover change (total change, change towards natural and change towards artificial), we divided the 716 PAs into categories according to their size and for each size class we calculated the mean rates of change (total change, change towards natural and change towards artificial). Since the subdivision into classes is subjective and can potentially influence the outcome of the analyses, we used 9 different possible legends, with a minimum of 7 and a maximum of 11 classes (table 1).

We used Spearman rank correlation analysis to test for a relationship between the mean land-use/land-cover change (total change, change towards natural and change towards artificial) and the size of PAs, performing a total of 27 (three cell sizes by nine different legends) correlation analyses. We performed the same analyses for the buffers for a total of 27 possible combinations (one buffer size by three cell sizes by nine different legends).

The previous analyses treat the PAs as a group. We also compared individual PAs with their surrounding areas to determine the percentage of functioning individual parks. For each size class, we calculated the percentage of PAs that changed more than the respective buffer towards natural land-use/land-cover and the percentages of PAs that changed more than the buffer towards artificial land-use/land-cover and we measured the Spearman rank correlation existing between the two percentages and the size of PAs (three cell sizes by one buffer sizes by nine legends by two types of change for a total of 54 correlation analyses).

To investigate whether the results were driven by some local pattern or were common to the entire study area, we divided the study area into three more homogeneous ecological and socio-economic macro-regions (the Alps, the Apennines, flat areas and coastal plains), slightly modifying the scheme proposed by Falcucci *et al.* (2007). For each of the macro-regions, we performed the same Spearman rank correlation analyses described previously.

Table 1. Classification schemes adopted to classify PAs according to their area (measured as km^2). The number of PAs in each size class is indicated in parentheses.

legend 1	<1 (250)	1–05 (205)	5–10 (68)	10–50 (105)	50–100 (35)	100–500 (36)	>=500 (17)				
legend 2	<1 (250)	1–5 (205)	5–10 (68)	10–50 (105)	50–100 (35)	100–250 (22)	250–500 (14)	>=500 (17)			
legend 3	<0.5 (186)	0.5–1 (64)	1–2.5 (117)	2.5–5 (88)	5–10 (68)	10–50 (105)	50–100 (35)	100–500 (36)	>=500 (17)		
legend 4	<1 (250)	1–5 (205)	5–10 (68)	10–25 (63)	25–50 (42)	50–100 (35)	100–250 (22)	250–500 (14)	>=500 (17)		
legend 5	<0.5 (186)	0.5–1 (64)	1–2.5 (117)	2.5–5 (88)	5–10 (68)	10–50 (105)	50–100 (35)	100–250 (22)	250–500 (14)	>=500 (17)	
legend 6	<0.5 (186)	0.5–1 (64)	1–2.5 (117)	2.5–5 (88)	5–10 (68)	10–25 (63)	25–50 (42)	50–100 (35)	100–250 (22)	250–500 (14)	>=500 (17)
legend 7	<0.5 (186)	0.5–1 (64)	1–2.5 (117)	2.5–5 (88)	5–10 (68)	10–50 (105)	50–100 (35)	100–250 (22)	>=250 (31)		
legend 8	<1 (250)	1–5 (205)	5–10 (68)	10–25 (63)	25–50 (42)	50–100 (35)	100–250 (22)	>=250 (31)			
legend 9	<0.5 (186)	0.5–1 (64)	1–2.5 (117)	2.5–5 (88)	5–10 (68)	10–25 (63)	25–50 (42)	50–100 (35)	100–250 (22)	>=250 (31)	

Table 2. Rate of change measured for the five types of reserves. Median and interquartile ranges are calculated considering the rate of change over three different cell sizes: 100, 200 and 300 m.

	median (%)	interquartile range (%)
national parks	4.9	13.7
national reserves	1.1	7.4
regional parks	5.1	11.8
regional reserves	7.8	21.1
other protected areas	8.7	23.8

To test the statistical significance of all the correlations we measured, we controlled for the positive false discovery rate using the q-value methods developed by Storey (2002), Storey & Tibshirani (2003) and Storey *et al.* (2004). The q-value is a measure that is analogue to the classical p-value (Roback & Askins 2004) and it provides a measure of each feature's significance, automatically taking into account the fact that many tests are being performed simultaneously (Storey & Tibshirani 2003). All significance tests were carried out at the $\alpha=0.05$ level using SAS statistical software and Q-value software (http://faculty.washington.edu/jstorey/qvalue/index.html accessed on 11/13/2007).

3. RESULTS

We are presenting the results obtained considering only the 2.5 km buffer. The results obtained with the 1 and 5 km buffers were not different from those presented below.

The rate of change measured for national PAs was lower than that measured for regional and local PAs (table 2); in particular, national reserves experienced a rate of change that was significantly lower than that of all the other types of reserve, while no significant difference was measured among national parks, regional parks, regional reserve and other PAs due to the high variability of the land-use/land-cover change rates (K–W=19.065, $p=0.0008$).

Overall, PAs changed significantly less than the surrounding buffers (Mann–Whitney U-test: $z=-2.3$; $p=0.0240$). No significant result was found considering only changes towards natural land-use/land-cover classes (Mann–Whitney U-test: $z=1.6$; $p=0.1092$), but considering only changes towards artificial classes, we found that the rate of change was significantly higher in the buffers than in the PAs (Mann–Whitney U-test: $z=-13.4$; $p<0.0001$).

We measured a significant negative correlation between PA size and the total rate of land-use/land-cover change (figure 1; table A1 in the electronic supplementary material). No significant relationship between buffer area and total rate of land-use/land-cover change was found (table A1 in the electronic supplementary material).

We measured a positive correlation between PA size and the rate of change towards natural land-use/land-cover classes, but the relationship was not strongly supported by the analyses (figure 2, table A2 in the electronic supplementary material). On the contrary, we found a negative correlation between PA size and the rate of change towards artificial land-use/land-cover classes, with 18.5% of the combinations being significant at the

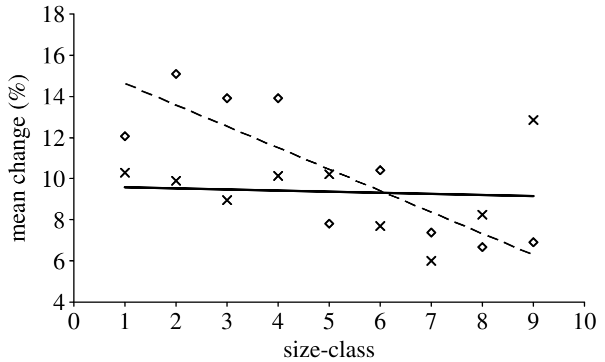

Figure 1. Spearman rank correlations measured between mean land-use/land-cover change and PA size, and between mean land-use/land-cover change and the buffer size. Only the r value with the median q-value is shown. The correlation was measured across three different cell sizes and nine different size-class legends (table A1 in the electronic supplementary materials). Diamonds, dashed line, PAs ($r=-0.850$; $q=0.0283$) and crosses, solid line, buffer ($r=-0.200$; $q=0.5493$).

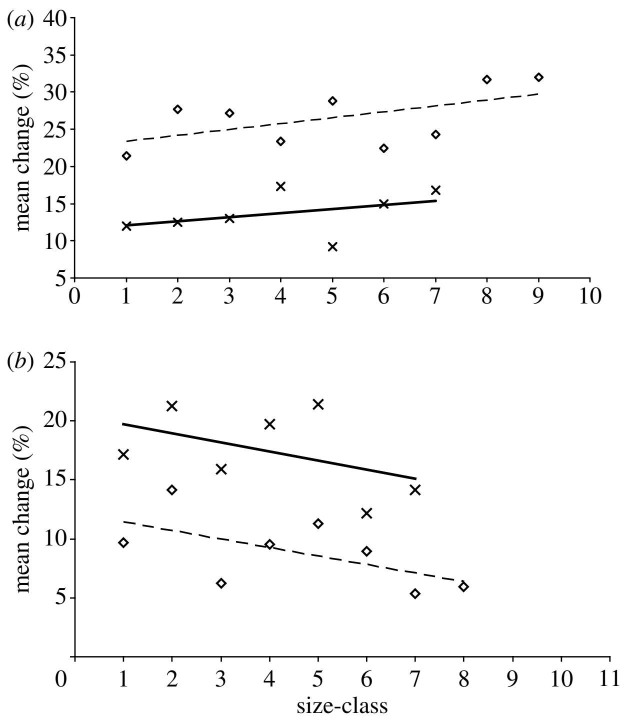

Figure 2. Spearman rank correlations measured between mean land-use/land-cover change and PA size, and between mean land-use/land-cover change and the buffer size towards (*a*) natural classes and (*b*) artificial classes. Only the r value with the median q-value is shown. The correlation was measured across three different cell sizes and three different size-class legends (table A2 in the electronic supplementary materials). (*a*) Diamonds, dashed lines, PAs ($r=0.583$; $q=0.1815$) and crosses, solid line, buffer ($r=0.464$; $q=0.2641$). (*b*) Diamonds, dashed line, PAs ($r=-0.690$; $q=0.1385$) and crosses, solid line buffer ($r=-0.429$; $q=0.2843$).

$\alpha=0.05$ level and 37% of the combinations being significant at the $\alpha=0.1$ level (table A2 in the electronic supplementary material). No significant correlation (both at the $\alpha=0.05$ and 0.1 levels) was found for the buffers (table A2 in the electronic supplementary material).

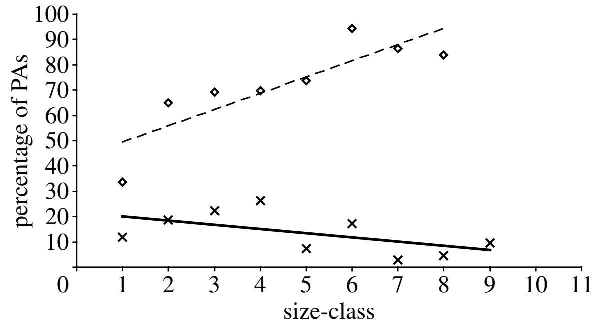

Figure 3. Spearman rank correlations measured between PA size and percentage of PAs with a mean change towards natural land-use/land-cover class which is greater than the respective buffer, and between PA size and percentage of PAs with a mean change towards artificial land-use/land-cover class which is greater than the respective buffer. Only the r value with the median q-value is shown. The correlation was measured across three different cell sizes and nine different size-class legends (table A3 in the electronic supplementary materials). Diamonds, dashed line, natural ($r=0.905$; $q=0.0019$) and crosses, solid line, artificial ($r=-0.600$; $q=0.0292$).

PA size was positively correlated with the percentage of PAs that changed more than their buffer towards natural land-use/land-cover, with 100% of the combinations being significant (figure 3; table A3 in the electronic supplementary material). We also measured a negative correlation between PA size and the percentage of PAs that changed more than their buffer towards artificial land-use/land-cover, with 77.8% of the combinations being significant at the $\alpha=0.05$ level and 100% of the combinations being significant at the $\alpha=0.1$ level.

(a) *The Alps*

The results obtained for the Alps were comparable to those obtained at the national level, even though the number of PAs in each size class was lower (total number of PAs in the Alps is 159, with only 23 PAs larger than 50 km^2). All combinations gave a significant negative rank correlation among PA size and the total rate of land-use/land-cover change, while only 55.6% of the combinations gave a comparable result for the buffers (full details on the results obtained for the Alps are provided in the relative electronic supplementary material).

No significant correlation was found in the Alps between PA size or buffer size and the rate of change towards natural land-use/land-cover classes. Considering changes towards artificial land-use/land-cover classes, 77.8% of the combinations gave a significant negative correlation for the PAs, while no combination was significant for the buffers.

The positive correlation among Alpine PA size and the percentage of Alpine PAs that changed more than their buffers towards natural land-use/land-cover was significant for 92.6% of the combinations. We also measured a negative correlation among Alpine PA size and the percentage of Alpine PAs that changed more than their buffers towards artificial land-use/land-cover, with all the combinations being significant.

(b) *The Apennines*

The Apennines host 167 PAs, but only 32 of them are larger than 50 km^2, making it difficult to obtain a reasonable number of PAs per size class in higher classes. The results obtained for the Apennines were not comparable to those obtained at the national level (full details on the results obtained for the Apennines are provided in the relative electronic supplementary material). In fact, only 11.1% of the correlations among PA size and the total rate of land-use/land-cover change were significant. The correlation between buffer size and total rate of land-use/land-cover change was never significant.

No clear relationship was measured in the Apennines between PA size or buffer size and the rate of change towards natural land-use/land-cover classes. The same was true for changes towards artificial land-use/land-cover classes.

The positive correlation between the PA size and the percentage of PAs that changed more than their buffers towards natural land-use/land-cover was always significant. On the contrary, only 14.8% of the combinations were significant considering PAs that changed more than their buffers towards artificial land-use/land-cover.

(c) *Flat areas and coastal plains*

Flat areas and coastal plains host 390 PAs, but only 34 of them are larger than 50 km^2. In this macro-region, the negative correlation between PA size and the total rate of land-use/land-cover change was significant for 51.2% of the combinations (full details on the results obtained for flat areas and coastal plains are provided in the relative electronic supplementary material). The correlation between buffer size and total rate of land-use/land-cover change was never statistically significant.

No clear relationship was measured between PA size or buffer size and the rate of change towards natural land-use/land-cover classes. The same was true for changes towards artificial land-use/land-cover classes.

The positive correlation between PA size and the percentage of PAs that changed more than their buffers towards natural land-use/land-cover was extremely strong, with 100% of the combinations being significant. On the contrary, only 3.7% of the correlations between PA size and the percentage of PAs that changed more than their buffers towards artificial land-use/land-cover were significant.

4. DISCUSSION

Even though any analysis of land-use/land-cover change is subject to technical problems (Coppin & Bauer 1996; Petit & Lambin 2001, 2002), our results can be considered fairly robust. In fact, while the two CORINE land cover maps were created from two basically different datasets (the CORINE Land Cover 1990 was realized using Landsat 5 images and other ancillary maps; the CORINE Land Cover 2000 was realized using Landsat 7 ETM+ images and a different set of ancillary maps), both were realized using the same methodology and the same land-use/land-cover classes (for more information visit the official CORINE land cover website at the EIONET, European Topic Centre on Land Use and Spatial Information: http://terrestrial.eionet.europa.eu/CLC2000). Even though EIONET recommends the use of a specific CORINE database to analyse any type of land use change (http://terrestrial.eionet.europa.eu/CLC2000/changes), Falcucci *et al.* (2007) have clearly demonstrated that the original CORINE land cover layers can be used with no problem. Moreover, European Environmental Agency (EEA 2006) found that CORINE Land Cover 2000, considering the third level of its hierarchical legend, classifies correctly 87% of 8115 field samples. We have no validation for CORINE Land Cover 1990, but we can assume that the error rate was not much different. Moreover, we used only the first level classes of the CORINE legend, thus further minimizing the possible errors.

The PA coverage was extensively checked by Maiorano *et al.* (2006) and most of the errors were corrected. We could not exclude that all co-registration errors (between the two land-use/land-cover maps and between the land-cover maps and the PA map) had been removed, thus we performed our analyses using three different cell sizes.

Performing a large number of statistical tests can potentially create a problem with the significance of the results obtained (Rice 1989; Roback & Askins 2004). Thus, we tested the statistical significance of our results using the q-value approach (Storey 2002; Storey & Tibshirani 2003; Storey *et al.* 2004), which allows for a robust and powerful alternative to the classical p-value in case many simultaneous tests are being performed.

An important caveat on our results is given by their purely quantitative aspects. The data available on land-use/land-cover do not permit any insight into changes in biomass. However, Tellini-Florenzano (2004) measured, for a national park in the Apennines, a significant ageing for different types of woods (*Fagus sylvatica, Quercus cerris* and other broadleaves, *Abies alba* and other conifers). This trend, combined with the retention of dead and dying trees, indicates that the ecological functionality of these forests and woods is potentially fully retained (Falcucci *et al.* 2007). Obviously, we cannot extrapolate these results to the entire Italian peninsula, since the national park considered by Tellini-Florenzano (2004) covers just 36 000 ha, but there is, at least, an indication of the ecological trends in the land-use/land-cover change that we measured.

Our main finding is that PAs (both considered singularly and as a system) have been effective at protecting the ecosystems within their borders, even in areas with significant and widespread land use pressures (see our results for flat areas and coastal plains). In fact, comparing PAs with neighbouring areas, we clearly demonstrated that PAs are effective at slowing down land-use/land-cover change. Bruner *et al.* (2001) obtained similar results but used a dataset built on questionnaires, and their study was harshly criticized (Vanclay 2001), mainly because their dataset was considered anecdotal rather than substantive. Our results, on the contrary, are based on objective datasets (both CORINE land cover maps can be freely downloaded from the European Environmental Agency website, and the PA coverage can be obtained from the Italian Ministry of the Environment—Directorate for Nature Conservation) that were extensively validated in the field.

Considering land-use/land-cover change without distinguishing the direction of change, there is a clear and statistically significant negative correlation between mean change and PA size. More particularly, we were not able to find any relationship among PAs considered altogether and change towards natural land-use/land-cover classes, but we found that PAs change towards artificial land-use/land-cover classes significantly less than neighbouring control areas.

We have also been able to confirm our initial hypothesis. In particular, considering our results at the national level, we can infer that by increasing the size of PAs, it is possible to favour the change towards more natural habitats and to slow down the change towards artificial habitats (figure 3).

This is particularly evident from the results that we obtained for the Alps, the Apennines and the flat areas and coastal plains. In fact, even with the obvious interpretation problems (splitting our sample of PAs, we obtained three sub-samples with a low number of large PAs, especially for the Alps and the Apennines; this implies that the results obtained for the single macro-regions should be considered with caution), we obtained a confirmation of our general results both for areas dominated by land-cover changes towards natural habitats and for areas with a very strong human influence. Falcucci *et al.* (2007) showed that the Italian alpine range changed from 1990 to 2000 towards a more natural condition, and we have demonstrated that PAs along the alpine range changed towards natural land-use/land-cover classes more than the rest of the macro-region (with larger PAs changing the most), while the change towards artificial land-use/land-cover classes was lower (with larger PAs changing the least).

From 1990 to 2000, the Apennines also showed a marked change towards natural land-use/land-cover classes (Falcucci *et al.* 2007). We were not able to demonstrate a correlation between PA size and the change towards artificial land-use/land-cover classes. This is probably linked to the fact that most of the mid-mountain areas along the Apennines (i.e. most of the areas along the borders of PAs) have been abandoned and naturally reforested (Falcucci *et al.* 2007), favouring a land-use/land-cover change towards natural classes. However, we demonstrated that PAs almost always change towards natural land-use/land-cover classes more than their buffers and larger PAs change the most.

Flat areas and coastal plains are the areas where the contrast among PAs and their buffers is greatest. In these areas, most of the changes in the 1990–2000 time frames moved towards artificial land-cover classes (Falcucci *et al.* 2007) and, even though all PAs were efficient in slowing down changes towards artificial land-use/land-cover classes, we found a particularly clear relationship between PA size and their efficacy.

The size of PAs has already been related to loss of species, with smaller (isolated) PAs having significantly more problems of species loss than larger ones (Terborgh 1974; Diamond 1975). The SLOSS debate focused on many different aspects, mainly relating PA size to species survival or to the number of species (Ovaskainen 2002). Along the same line, but using completely different analyses, McKinney (2005) found that larger parks in the USA have relatively less human access for disturbance, with significant advantages over smaller parks. Moreover, Shafer (1995) reviewed possible sources of damage or threats for small PAs.

However, the problem has never been analysed considering the efficacy of PAs in slowing and/or halting habitat degradation and in favouring habitat restoration. Our results provide, from this point of view, very clear indications towards the importance of large PAs, not only in pristine environments, but also in areas where the main habitat characteristics are and have been shaped by traditional human activities for thousands of years.

A simple explanation of our results may rely on the ecological mechanisms that link PAs to the surrounding lands. Hansen & DeFries (2007) suggest that small PAs are often part of larger ecosystems and thus their biodiversity and their ecological processes are heavily influenced by what is going on outside their boundaries. Here, we are suggesting that socio-economic phenomena (and other human-related characteristics of PAs) follow the same pattern: larger PAs have their own identity and their own dynamics, while smaller PAs are usually part of larger socio-economic systems and follow the fate of those systems.

More generally, our results suggest that small PAs are not going to be viable in the long term if they are considered as islands surrounded by a ‘human-dominated ocean’ for reasons beyond those of the extinction/recolonization dynamics of animal and plant species. In fact, it is highly probable that ‘negative’ land-use/land-cover changes will continue in the foreseeable future, even exacerbated by climate change (Chapin *et al.* 2000). This trend implies that, in a human-dominated landscape, small PAs will sooner or later (probably later than the surrounding areas) lose all the characteristics for which they have been established. However, small PAs are, in most of the western European countries, the only option available for *in situ* conservation, and actually they are important for the conservation of small habitat features and of species with limited habitat requirements (Schwartz 1999), especially when considered as part of a coherent network (Fischer & Lindenmayer 2002).

We are not suggesting that we should dismiss small PAs. Conservation areas are still the most important tool available for conservation (Chape *et al.* 2005; Lovejoy 2006), but we need to operate an important shift in our strategies. We cannot rely blindly on a tool that, at least in the industrialized world, is doomed to failure, but we need to change our management strategies and devote much more attention to the non-protected matrix in which PAs must survive.

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